Establishing Typical Range of Values and Comparison of DGA Methods in MATLAB for Transformer Population in Malaysia

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ABSTRACT: Power transformer uses mineral insulating oil as the insulator and cooling agent. During operation, the insulating oil in the power transformer is prone to covalent bonds of the oil to breakdown and form different kinds of fault gases. The fault type that has occurred in a power transformer can be diagnosed using analysis techniques such as the Dissolved Gas Analysis (DGA). The DGA diagnoses the type of fault in the transformer based on the composition of the fault gases generated. In this paper, typical range of values are used to assess the severity of the fault type with 90th and 95th percentile value of 3389 transformer oil gas data in 490 different transformers. The outcome shows that the Duval Triangle method returns effective diagnostic results due to its close-loop nature.

Keywords: *DGA; insulating oil; fault gas.*

1. INTRODUCTION

Power transformers are the backbone of a power system that link generators and the transmission lines. During operation, the insulating-oil of the power transformer is obliged to experience constant electrical or thermal stresses; hence, the insulating-oil may breakdown into smaller fragments of gases known as fault gases. A common approach to analysing these fault gases in the insulating oil is the DGA. The DGA diagnoses the type of fault in the transformer based on the composition of the fault gases generated. In DGA, the fault related gases commonly are hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4) and ethane (C_2H_6). A common approach to diagnose the fault type of the transformers are Roger's Ratio Method, IEC Ratio Method, Doernenburg's Ratio Method, Key Gas Method and Duval Triangle Method. The DGA is advantageous because the operator need not to de-energise the transformer to identify the incipient or active fault in the transformer. Therefore, establishing a typical range of values for the transformer population is encouraged in both the IEEE C57104 and IEC 60599 standards, as user will be able to assess the condition of the transformer and suitable actions to be taken for transformers deemed in abnormal conditions [1].

2. METHODOLOGY

Typical range of values were extracted from 3389 oil gas data from 490 different transformers rated at 33/11kV in Malaysia. The oil gas data comprises of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4) and ethane (C_2H_6). A typical range of values for the gas concentration levels and rate of change in levels between samples was observed based on IEEE C57104:2019 and IEC 60599:2016 standards [2][3]. As the typical values established by both standards were based on transformers from other locations, the typical fault gas levels in Malaysia may differ from the two standards. The standards recommended that the utilities propose a typical range of values, or norm values, for their own transformer population [3]. Hence, it stands to reason the importance of establishing a norm value using the oil sample data of transformers operating in Malaysia. This norm value will be constructed using 90th and 95th percentile of the fault oil gas data concentration according to three different age categories namely age 1-9 years, 10-30 years and more than 30 years. The sample calculation for 90th percentile is 90/100 times the oil gas value.

3. RESULTS AND DISCUSSIONS

The computed 90th and 95th percentile values rounded to the nearest ten, hundred, or thousand and are in units μL/L(ppm).

Table 1: 90th and 95th percentile values

Gas Type/ Transformer Age	Aged 1-9		Aged 10-30		Aged > 30	
	90th	95th	90th	95th	90th	95th
Hydrogen, H_2	310	340	170	260	70	130
Methane, CH_4	50	100	90	150	40	90
Carbon Monoxide,CO	460	500	780	970	630	740
Carbon Dioxide, CO_2	3300	3400	7400	9000	7000	7800
Ethylene,C_2H_4	13	15	60	110	100	120
Ethane, C_2H_6	130	300	150	300	20	60
Acetylene, C_2H_2	1	2	19	30	5	20

After 90th and 95th percentile values were obtained from 3389 oil gas data from 490 different transformers rated at 33/11kV in Malaysia, the values were further analysed in MATLAB using five common DGA methods of fault gas analysis namely Roger's Ratio (RR) IEC (IEC) Ratio, Doernenburg's Ratio (DR), Key Gas (KG) and Duval Triangle (DT) as mentioned in the IEEE and IEC standards [2][3]. The faults are grouped in Table 2 based on the standards [2][3]. The outcomes of the data analysis are showed in Table 3, 4 and 5.

Table 2: Grouping of fault diagnosis

Method	F1	F2	F3	F4	F5	F6
RR	Slight overheating <150°C Overheating 150°C-200°C Overheating 200°C-300°C	Conductor Overheating Winding Circulating Current Core/Tank Circulating Current	Flashover Arcing Continuous Sparking	PD PD with tracking	Normal	N/A
IEC	Thermal Fault < 150°C Thermal Fault 150°C - 300°C	Thermal Fault 300°C - 700°C Thermal Fault > 700°C	Low Energy Discharge High Energy Discharge	Low Energy Density PD High Energy Density PD	Normal	N/A
DR	Thermal Decomposition		Arcing	PD	Normal	N/A
KG	Overheated Cellulose	Overheated Oil	Arcing	PD	N/A	N/A
DT	Thermal Fault < 300°C	Thermal Fault 300°C-700°C Thermal Fault >700°C	Low Energy Discharge, D1 High Energy Discharge, D2	PD Mixture of Thermal and Electrical	N/A	N/A

Table 3: Fault diagnosis percentage for aged 1-9 years

Method	F1	F2	F3	F4	F5	F6
RR	30	0	0	30	20	20
IEC	0	28.6	0	28.6	28.6	14.2
DR	0	0	0	10	80	10
KG	0	0	0	0	-	100
DT	60	10	0	30	-	-

Table 4: Fault diagnosis percentage for aged 10-30 years

Method	F1	F2	F3	F4	F5	F6
RR	32.8	10.3	8.4	1.1	6.8	40.6
IEC	20.3	7.9	17.7	7	16.1	31
DR	10.2	10.2	4.2	4.5	53.4	27.7
KG	16	0.1	0	0	-	83.9
DT	28	40.8	16.6	14.6	-	-

Table 5: Fault diagnosis percentage for aged 30 years+

Method	F1	F2	F3	F4	F5	F6
RR	14.7	7.8	2	6.9	4.9	63.7
IEC	20.6	14.7	16.7	2.9	6.9	38.2
DR	10.8	10.8	1	1	58.8	28.4
KG	5.9	0	0	3	-	91.1
DT	4	67.3	7	21.7	-	-

Based on Table 3 to 5, DT method is the most successful in returning a confirmed diagnostic result as compared to other methods. Due to its close-loop nature, the DT method can reliably provide a diagnostic result. Succeeding the DT method are the IEC with results ranging from 61.8% - 85.5% and DR method, with the results ranging from 71.6% - 90%. Second to last is the RR method at 36.3% - 80% and KG method at 0% - 16.1%. Figure 1 shows the MATLAB GUI is created. By entering the serial number, fault gas data will be extracted and appeared. Then, "Proceed with Diagnosis" will shows the outcomes of the transformer health.

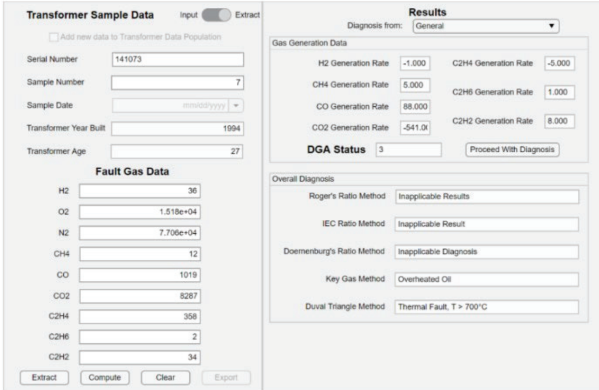

Figure 1: MATLAB GUI with Serial Number entered.

In the "Results" side, the "Diagnosis from" could be choose from any one out of the five DGA common methods of fault types. For example, DT method is chosen and shown in Figure 2.

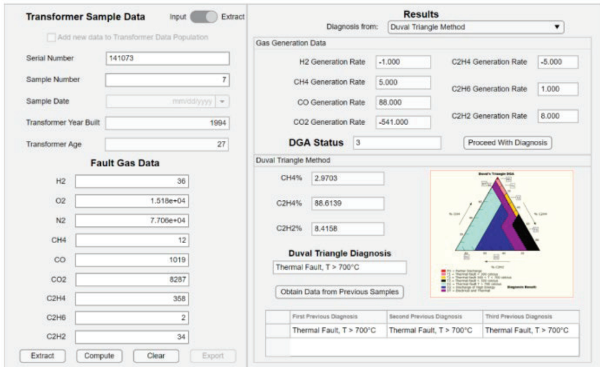

Figure 2: Duval Triangle Method Panel in MATLAB GUI.

4. CONCLUSION

In conclusion, the typical range of values were extracted from 3389 oil gas data from 490 different transformers rated at 33/11kV in Malaysia. The oil data has been processed in 90th and 95th percentile according to three different age categories namely age 1-9 years, 10-30 years and more than 30 years. The effectiveness of the fault diagnosis using five common DGA methods in MATLAB GUI have been evaluated and compared. Finally, the MATLAB GUI allows user to obtain the diagnosis results from one or all five DGA common methods.

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